

XXIV INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS

Munich, August 4 - 10, 1988

Parallel Session 19: The Physics at the Planck Scale

Speaker: V. Rubakov

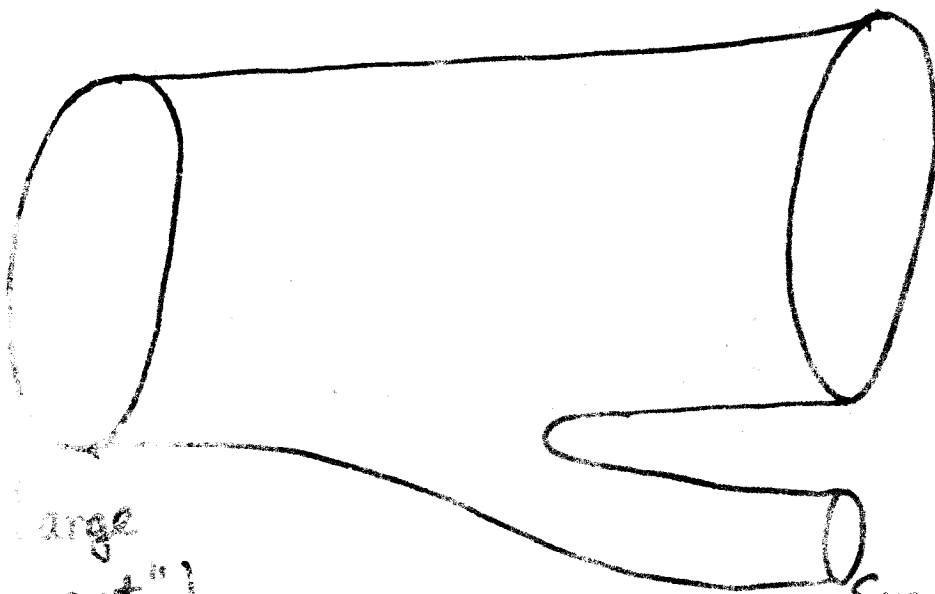
Topic: Baby universes and
Symmetric Coupling Constants

BABY UNIVERSES

AND

DYNAMICAL COUPLING CONSTANT

POSSIBLE ROLE OF TOPOLOGICAL CHANGES



Large
Universe

Large
(parent)
universe

Small ("Baby")
universe

$r \sim L_{\text{Planck}}$

COMPLETE LIST OF
RECENT PAPERS:

- * S. HAWKING Phys. Lett (87)
 Phys. Rev. (88)
- * G. LAURELASHVILI, Pisma ZhETF (87)
 V. R., P. TINYAKOV Nucl. Phys. (88)
- * S. GIDDINGS, HUTP PREPRINTS (87, 88)
 A. STROMINGER
- * S. COLEMAN HUTP PREPRINTS (88)
- * T. BANKS SANTA CRUZ PREPRINT (88)

ALSO TO APPEAR:

- * S. GIDDINGS, A. STROMINGER
- * G. LAURELASHVILI, V. R., P. TINYAKOV
- * I. KLEBANOV, L. SUSSKIND, T. BANKS
 V. R., P. TINYAKOV

NOW SEEMS THAT
COUPLING CONSTANTS OF NATURE
ARE "DYNAMICAL VARIABLES".

"DYNAMICAL" DOES NOT MEAN
DEPENDENCE ON SPACE-TIME POINT.
RATHER, "DYNAMICAL" MEANS
THAT ACTUAL VALUES OF
COUPLING CONSTANTS (AS OBSERVED
BY US) ARE DETERMINED BY
"GAP EQUATION" WHICH INVOLVES
OVERALL HISTORY OF UNIVERSE(S)
IN PARTICULAR, BY OUR PAST
AND FUTURE.

IN THIS WAY ONE HOPES TO
EXPLAIN ZERO LOW ENERGY VALUE
OF THE COSMOLOGICAL CONSTANT.

ISSUE IS HIGHLY CONTROVERSIAL
AND SPECULATIVE (AT THE MOMENT?)

NO CONVINCING ARGUMENTS
FAVOURING ZERO L.E. COSMOLOGICAL
CONSTANT ARE GIVEN YET.

PLAN

- * DEVIATION: COSMOLOGICAL CONSTANT PROBLEM
- * TOPOLOGICAL CHANGES AND OPERATOR COUPLING CONSTANTS
- * COLEMAN'S ARGUMENT FOR $\Lambda_{LE} = 0$
- * SELF-CREATION OF UNIVERSES.

NO DISCUSSION OF THIRD QUANTUM
(ALTHOUGH VERY RELEVANT AND
CONVENIENT(?)).

ATION:

SMOLOGICAL CONSTANT PROBLEM

OBSERVATIONS: $\Lambda_{L.E.} = 0$ AT HIGH PRECISION
L.E. MEANS 10^{28} cm.

* THIS IS LOW ENERGY PROBLEM:

$\Lambda_{L.E.}$ = VACUUM ENERGY DENSITY

RECEIVES CONTRIBUTIONS FROM LOW
ENERGY DYNAMICS (QCD VACUUM, etc.)



BARE $\Lambda = 0$ (DUE TO, E.G., HIGH ENERGY
SUPERSYMMETRY) IS NOT ENOUGH

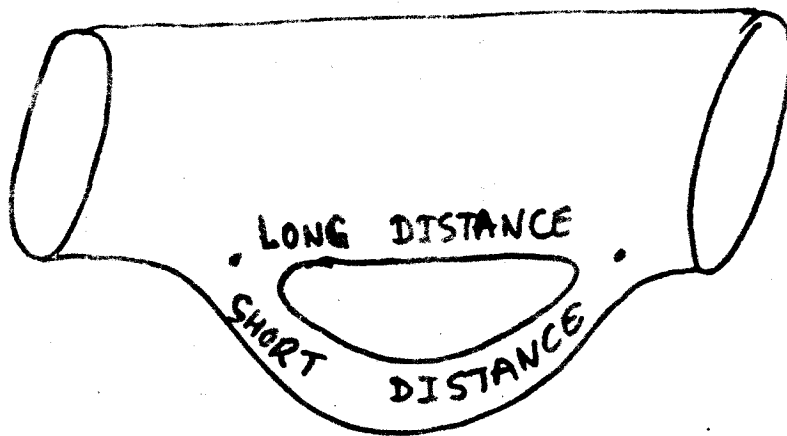
FANTASTIC FINE TUNING OF BARE Λ
IS REQUIRED TO SET $\Lambda_{L.E.} = 0$

OBSERVED $\Lambda_{L.E.}$ MUST SOMEHOW BE
DETERMINED BY GLOBAL PROPERTIES
UNIVERSE A. LINDE '88

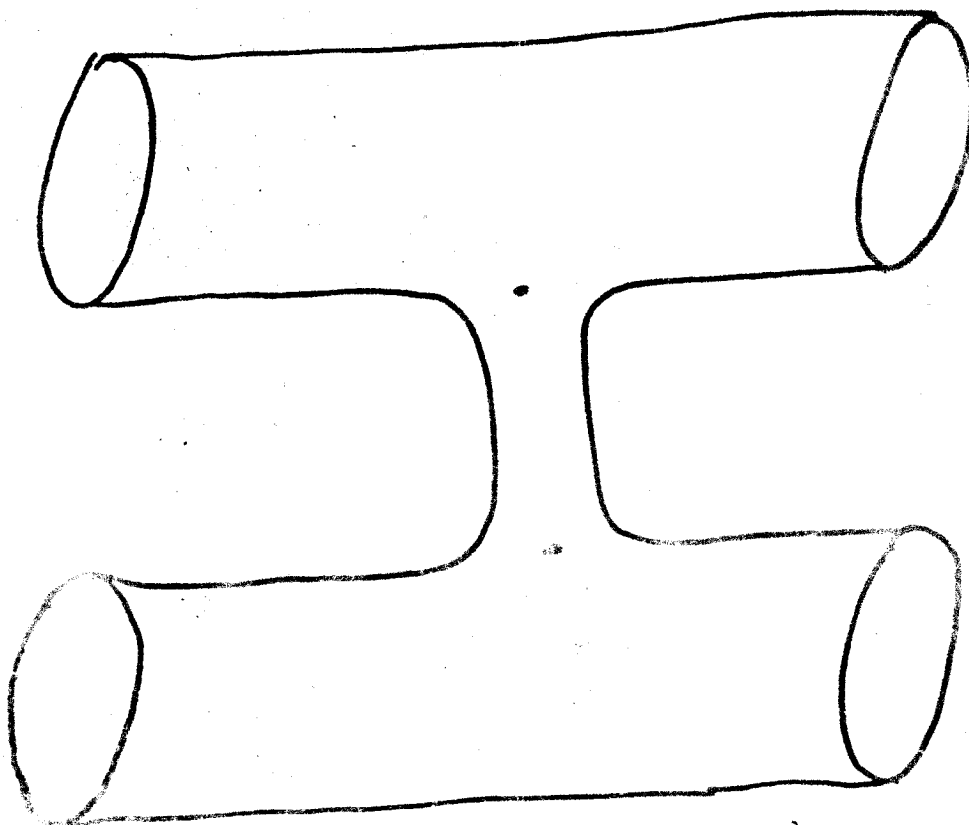


NON-LOCAL INTERACTIONS ARE NEEDED

AND PROVIDED BY
TOPOLOGICAL CHANGES:



OR/AND



LOGICAL CHANGES AND

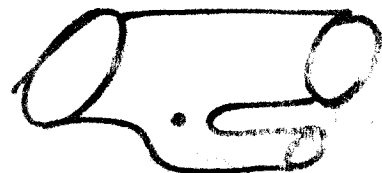
OPERATOR COUPLING CONSTANTS

* ENERGY, MOMENTUM, ELECTRIC CHARGE, ETC.
OF A CLOSED UNIVERSE ARE ZERO



CONSERVATION LAWS IN PARENT
UNIVERSE ARE NOT VIOLATED

* MINKOWSKI SIGNATURE MANIFOLDS
OF THIS SORT ARE SICK
(SINGULARITIES OR
CAUSAL ANOMALIES)



EUCLIDEAN SIGNATURE MANIFOLDS



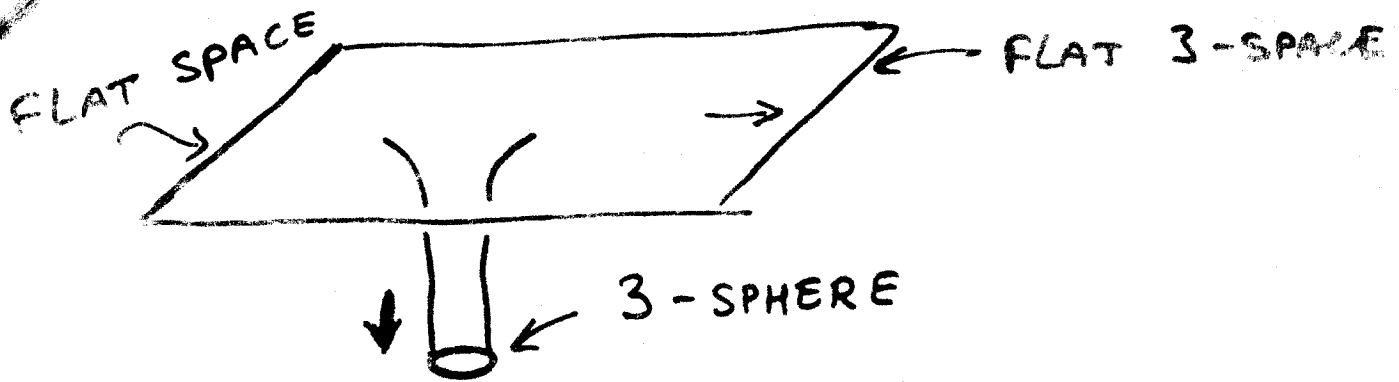
TUNNELING EVENTS

(?)

EUCLIDEAN
GRAV. ACTION
NOT POSITIVE

GRAVITATIONAL INSTANTONS

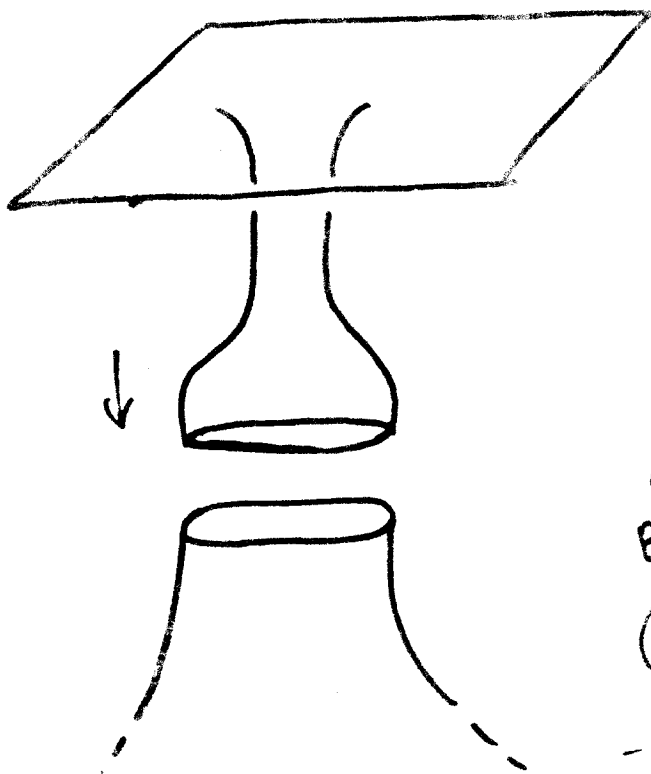
GIDDINGS AND STROMINGER (87)
(GRAVITY + $H_{\mu\nu\lambda}$)



ANALYTICAL CONTINUATION
BABY UNIVERSE COLLAPSES
DOWN TO SINGULARITY

(BABY DOES NOT GROW UP)

* V.R. AND TINYAKOV (88)
(GRAVITY + $H_{\mu\nu\lambda}$ + SCALAR FIELD)

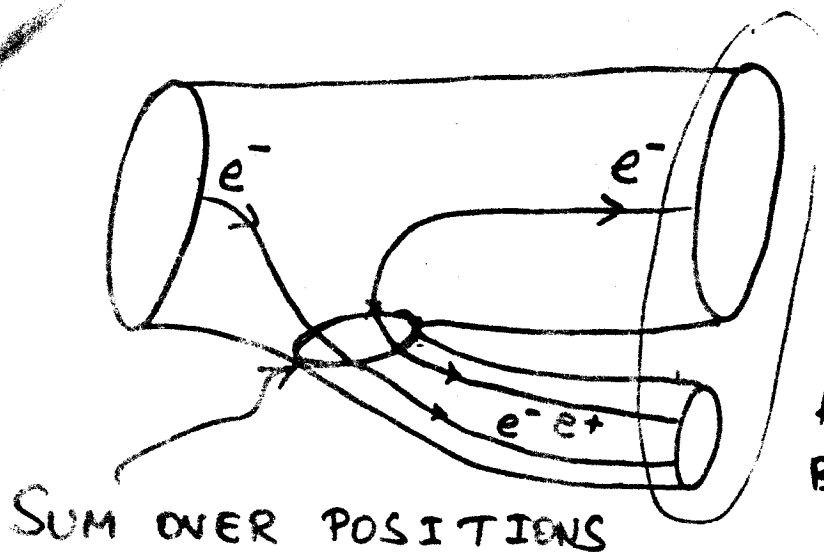


ANALYTICAL CONTINUATION
BABY UNIVERSE EXPANDS
(AND CAN BECOME PARENT)

UNDER FIRST G.-S.

PARTICLES INTERACT WITH INSTANTON

HAWKING '87
LRT '87



SUM OVER POSITIONS
OF A WORMHOLE

ANOTHER TYPE OF
BABY UNIVERSE
CREATED



SYSTEM HAS EXTRA DEGREES OF
FREEDOM (# OF SMALL UNIVERSES OF
GIVEN TYPE)

VIEWED FROM LARGE SCALES

Coleman '88

HAMILTONIAN = $H_0 + \sum_i \left(\int \mathcal{O}_i(x) d^3x \right) (a_i^\dagger + a_i)$
(WRT TIME OF
LARGE UNIVERSE)

LOCAL HERMITEAN
OPERATOR

OPERATOR
CREATING
BABY
UNIVERSE
OF i -th
type

$$\mathcal{O}_i = C_0, C_1 \bar{e}e, \dots$$

(LARGE SCALE INVARIANCE ALSO REMAINS)

COUPLING CONSTANTS :

(9)

$$\lambda_i^{\text{eff}} = \lambda_i^{\text{bare}} + C_i (a_i^+ + a_i)$$

$$H = \sum_i \lambda_i^{\text{eff}} \int \mathcal{O}_i d^3x$$

λ_i^{eff} not necessarily commute?

Model:
Giddings,
Strominger '88

(If not commute \Rightarrow non-local theory,
 $[\mathcal{H}(\vec{x}), \mathcal{H}(\vec{y})] \neq 0$).

ASSUME λ_i^{eff} commute

\Downarrow

DIAGONALIZE $(a_i^+ + a_i)|q\rangle = q_i|q\rangle$

\Downarrow

$\lambda_i^{\text{eff}} = \lambda_i^{\text{bare}} + C_i q_i$ in sector $|q\rangle$.

's are like \mathcal{O}_{QCD} .

COUPLING CONSTANTS ARE NOT YET DYNAMICAL
 Nevertheless one can attempt to "determine"
 preferred values of λ_i^{eff} .

IN GENERAL, STATE IS

$$\sum_q C_q |q\rangle \quad (\text{measure } q \Rightarrow \text{know where you are})$$

C_q be peaked at some values of $\{q_i\}$?

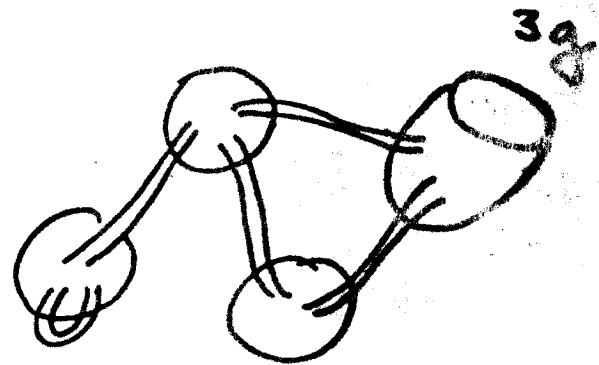
MAN'S ARGUMENT (88)

(u)

Close to Hawking's

C_q are given by Hartle - Hawking prescription

$$C_q[{}^3g] = \sum_{\substack{\text{EUCLIDEAN} \\ \text{4-geometries} \\ \text{with the only} \\ \text{boundary } {}^3g}} e^{-S_E({}^3g, \lambda_{\text{eff}})}$$



$$= \sum_{\substack{\text{smooth} \\ \text{geometries}}} e^{-\Gamma_E({}^3g, \lambda_{\text{L.E.}}^{\text{eff}})}$$

SUM IS ASSUMED TO BE SATURATED BY SADDLE-POINTS OF Γ_E (SOLNS. TO EUCLIDEAN EINSTEIN EQNS.)

$$\Gamma_E = \int d^4x \sqrt{g} (\Lambda_{\text{L.E.}} - M_{\text{Pl}}^2 R + \dots)$$

↑ Higher deriva

ONE SADDLE POINT:

4-SPHERE, $R = \text{const } M_{\text{Pl}} / \sqrt{\Lambda_{\text{L.E.}}}$

$$\Gamma_E(4S) = - \text{const } \frac{M_{\text{Pl}}^4}{\Lambda_{\text{L.E.}}}$$

TE GAS:

$$\chi \propto e^{e^{-\Gamma_E}} = e^{e^{+ \text{const.} \frac{M_{Pl}^4}{\Lambda_{L.E.}}}}$$

(11)

SHARPLY PEAKED AT $\Lambda_{L.E.} = +0$.

MAIN DRAWBACK:

THE WHOLE ARGUMENT IS BASED
UPON NON-POSITIVENESS OF
EUCLIDEAN GRAVITATIONAL ACTION,
WHICH IS UNDESIRABLE FEATURE
OF EUCLIDEAN QUANTUM GRAVITY.

PHYSICAL
THERE ARE ALSO REASONS NOT TO
BELIEVE EUCLIDEAN QUANTUM GRAVITY
IN THIS CONTEXT

Linde '85

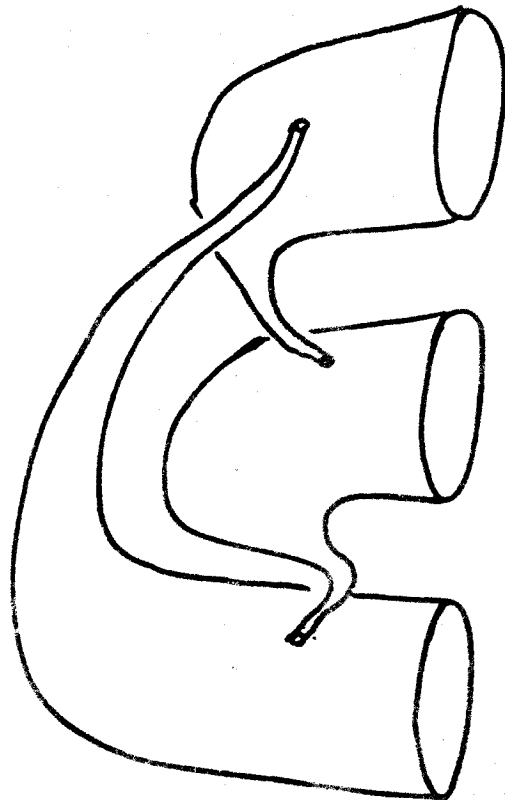
LRT '85

- CREATION OF UNIVERSES (12)

are instantons describing
reaction of expanding universes



SELF-CREATION OF UNIVERSES
IS POSSIBLE:



No overall time for the whole SYSTEM:
TIME IS CREATED TOGETHER WITH
OF A GIVEN UNIVERSE

THIS UNIVERSE.

UNIQUE BOUNDARY CONDITION: THERE ARE
NO UNIVERSES WITH VERY SMALL RADII.
(CREATION FROM NOTHING).

ON OPERATORS OF BABY
PARENT UNIVERSES.



COUPLING CONSTANTS ARE TO BE
DETERMINED BY SELF-CONSISTENCY
TRULY DYNAMICAL COUPLING CONSTANTS.

WHY STATE VECTOR COULD BE PEAKED
AT $\Lambda_{L.E.} = 0$?

GUESS: BECAUSE UNIVERSE WANTS
TO HAVE LARGE (MINKOWSKI)
SPACE-TIME VOLUME.

of created universes \propto Space-time volume
of one universe



The larger the space-time volume, the
number of big universes \Rightarrow the larger
the probability to be in one of them.

Negative $\Lambda_{L.E.} \Rightarrow \text{Volume} \sim \frac{1}{|\Lambda_{L.E.}|}$

Positive $\Lambda_{L.E.} \Rightarrow$ Universe expands rapidly,
space-TIME volume is
again small



$\Lambda_{L.E.}$ is going to be peaked at zero.

(14)
COUPLING CONSTANTS
ARE DETERMINED BY THE
LARGEST (IN THE SENSE OF
MINKOWSKI SPACE-TIME VOLUME)
PART OF THE HISTORY OF TYPICAL
UNIVERSE

ANOTHER POSSIBILITY: STATE
VECTOR IS NOT PEAKED \Rightarrow
ANTHROPIC PRINCIPLE CAN HELP.